Some Searches for New Physics with the D0 Detector

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SOME SEARCHES FOR NEW PHYSICS WITH THE D0 DETECTOR

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We present recent results on Technicolor and Leptoquark searches obtained analyzing up to 0.4 fb^{-1} of data taken at Fermilab by the D0 experiment during the first part of the Tevatron Run II.

Keywords: Tevatron; D0; Technicolor; Leptoquark.

1. Introduction

The Standard Model (SM), although phenomenologically successful, leaves many questions unanswered. To address some of these questions, new models and theories have been devised that need to be confronted with experimental facts. The Tevatron, providing $p\bar{p}$ collisions at a centre of mass energy of $\sqrt{s} = 1.96$ TeV, is presently the hadron collider at the energy frontier, and thus plays a leading role in the quest of phenomena Beyond the Standard Model (BSM). Numerous D0 results concerning BSM physics, related to the extension of the Poincaré group (Supersymmetry and Supergravity) [1], the increase in the number of space dimensions [2], the enlargement the gauge group [2], and the existence of a substructure to quark and leptons (compositeness) [3] have been shown at this conference. This contribution focuses on searches for Technicolor, which provides an alternative to the SM Electroweak Symmetry Breaking (EWSB) mechanism, and for Leptoquarks, ambivalent particles predicted by several extensions to the SM. A comprehensive list of results of D0 search analyses can be found in the experiment web pages[4].

2. Search for Technicolor

In the SM, the Higgs boson field is the key of the spontaneous EWSB mechanism. However, being a scalar particle, its mass is pushed by radiative corrections towards high energy (GUT or Planck) scales. This gives rise to the so-called hierarchy problem which can be solved *e.g.* by taming the quadratically divergent Higgs mass corrections making use of Supersymmetry. Alternatively, Technicolor (TC) does away with a fundamental scalar, but introduces technifermions subjected to a new stong dynamics *à la* QCD. In the original TC model [5], the coupling of the unbroken electroweak gauge fields to technifermion condensates provides a way to generate masses only to the W and Z vector bosons [5]. Some extensions [6] are necessary to make TC more phenomelogically satisfying. The analysis presented here is performed in the framework of the Technicolor Strawman Model (TCSM2) [7], well suited for the search for light technihadrons produced with substantial cross-section at the Tevatron. The lightest technifermions are expected to be color-singlet vector mesons (ρ_T and ω_T) and pseudo-scalar mesons (π_T^0 and $\pi_T^{\pm}$ also dubbed technipions). Cross-sections and branching fractions depend in particular on the ρ_T and ω_T masses, on their mass difference with the technipions, and on two mass parameters: M_A for the axial-vector and M_V for the vector couplings which are set here to $M_V = M_A = 500$ GeV.

2.1. *Event selection and analysis*

The analysis looks for production of ρ_T subsequently decaying as $\rho_T^{\pm} \to W^{\pm}(e\nu)\pi_T^0(b\bar{b})$ or $\rho_T^0 \to W^{\mp}(e\nu)\pi_T^{\pm}(c\bar{b}/b\bar{c})$. The first step is to select $W(e\nu)+$ heavy-flavor jets events. One requires exactly one electron with transverse momentum $p_T > 20$ GeV and pseudorapidity $|\eta| < 1.1$, missing transverse energy $\not{E}_T > 20$ GeV and transverse mass $M_T > 30$ GeV, two jets with $p_T > 20$ GeV and $|\eta| < 2.5$ with at least one of them b-tagged. The SM backgrounds, namely $t\bar{t}$ production and W/Z produced in association with heavy flavor jets are estimated using Monte Carlo simulations (MC). Multijet production with a jet mis-identified as an electron, and W + light flavor production with light jets mistagged as heavy jets comprise the instrumental background which is estimated from data. At that level there is a good agreement between the 115.1 events estimated for the sum of the backgrounds and the 117 found in data. Two startegies are then used to try to extract the signal, one is cut based (CB) and the other uses a neural network (NN).

The CB analysis uses kinematic and topological quantities to discriminate against $t\bar{t}$ and $W + jets$ production. The invariant mass of the dijet system M_{jj} is used to get indication of a π_T narrow resonance. The invariant mass of the $W + dijet$ system M_{Wjj} is used to look for a ρ_T narrow resonance. A mass dependant optimization is performed on signal significance. For example, for $M_{\pi_T} = 110$ GeV and $M_{\rho_T} = 210$ GeV, 12 events are seen in data for 12.7 ± 0.9 expected from backgrounds and 10.3 ± 1.0 from signal.

The NN analysis uses a two stage NN using 8 kinematic and topological variables to discriminate signal from $t\bar{t}$ and $W + jets$ production. A mass dependant optimization of the NN output cut is performed w.r.t. signal significance. An example of NN output is shown in Fig. 1 for $M_{\pi_T} = 105$ GeV and $M_{\rho_T} = 200$ GeV.

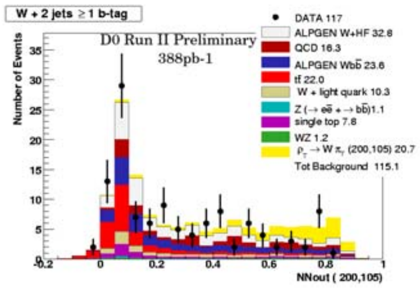

Fig. 1. Distribution of the output of the Neural Network in the $\rho_T \to W\pi_T$ analysis

2.2. *Results*

Since no excess of events is found in either analysis, limits are computed using Bayesian statistics (CB) and a 2-D maximum likelihood using (M_{Wjj},M_{jj}) correlations (NN). Figure 2 shows the observed and expected 95% C.L. exclusion contours for each analysis.

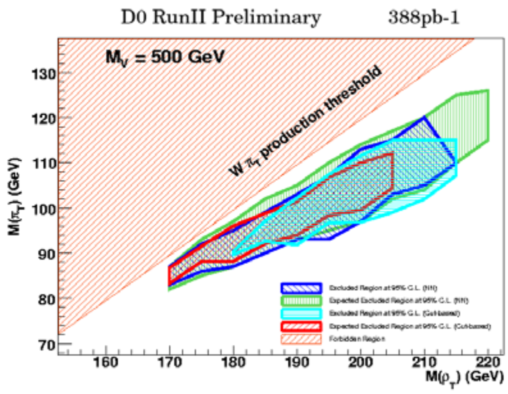

Fig. 2. Observed and expected 95% C.L. exclusion contours in the $M(\pi_T) vs. M(\rho_T)$ for the Cut and Neural Network based analyses. Regions excluded lie inside the corresponding contours

This is the first measurement done in

the TCSM2 framework. No evidence of production of techni-particules was found in 388 pb^{-1} of data. Including the μ channel and taking advantage of the increasing available luminosity should allow for an even larger TC parameter space exploration.

3. Search for Leptoquarks

Leptoquarks (LQ), exotic scalar or vector particles carrying the quantum numbers of a quark-lepton system, are predicted by some extensions to the SM which try to relate the apparent symmetry of the quark and lepton sectors. To avoid unacceptably large FCNC processes, the LQ's would come in three generations, each one coupling to a specific quark/lepton generation. They are expected to decay with a branching fraction β into a quark and a charged lepton and $(1-\beta)$ into a quark and a neutrino. At the Tevatron, if sufficiently light, they can be pair produced with a cross-section independant of the unknown LQ-quark-lepton coupling. First [8] and second [9] generation LQ searches in Tevatron Run II data have already been published by D0.

When both LQ's decay into a quark and a neutrino, the final state consists of 2 acoplanar jets and $\not\!\!E_T$. A first analysis is presented looking for LQ's of any generation in that final state. The second looks specifically for the 3rd generation taking advantage of the fact that in this case the jets come from the hadronization of b quarks and thus can be tagged as such. Only scalar LQ's are taken into account here since they have a smaller and less model dependant production cross-section.

Both analyses use 310 pb^{-1} of Tevatron Run II data recorded by D0, resulting in about 14 million events collected with a specific jets+$\not\!\!E_T$ trigger.

Backgrounds from SM processes (W/Z production associated with jets, diboson production, single- and pair-top production) are determined from MC simulations. The instrumental (also dubbed 'QCD') background in multijet production is estimated from data.

3.1. *Leptoquarks in the acoplanar jet topology analysis*

The selection criteria consist of: a rejection of events with obvious calorimeter noise, requirements on jet properties (acoplanarity $> 165^o$ between the 2 leading jets, $|\eta| < 1.5$ since the signal is central, $p_{Tj1} > 60$ GeV and $p_{Tj2} > 50$ GeV, energy fraction in the electromagnetic calorimeter < 0.95, to reject jets likely due to photons and electrons, charged particle fraction > 0.05, to avoid fake jets and wrong interaction vertices), a rejection of events with isolated electrons or muons with $p_T > 10$ GeV, or isolated track with $p_T > 5$ GeV. To further reduce the backgrounds, exactly 2 jets are required. A $\not\!\!E_T$ cut and cuts on angular correlations between jets and the direction of $\not\!\!E_T$ are optimized as a function of the LQ mass (M_{LQ}) and used to suppress both SM and instrumental backgrounds. The remaining instrumental background is estimated from extrapolations from fits to the $\not\!\!E_T$ distribution in the $[40, 60]$ GeV interval as shown in Fig. 3.

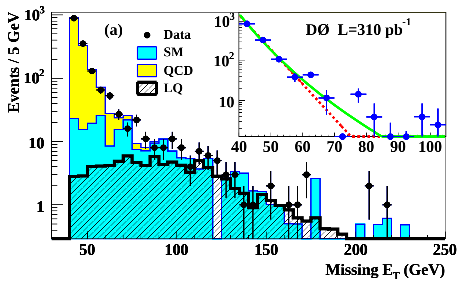

Fig. 3. Distribution of $\not\!\!E_T$, after all cuts but $\not\!\!E_T$ applied, and showing the good agreement between data and SM background at high $\not\!\!E_T$ and how the instrumental background is estimated.

As an example, after cuts optimized for $M_{LQ} = 140$ GeV, 86 events are observed for $72.9^{+10.1}_{-9.7}(stat.)^{+10.6}_{-12.1}(syst.)$ expected from SM backgrounds, 2.3 ± 1.2 estimated instrumental background, and $51.8 \pm 1.8(stat.)^{+5.6}_{-4.6}(syst.)$ signal events.

Since no excess is seen, the observed 95% C.L. excluded cross-section as a function of M_{LQ} is compared to the theoretical cross-section reduced by the renormalization scale and the PDF uncertainties summed in quadrature as shown in Fig. 4.

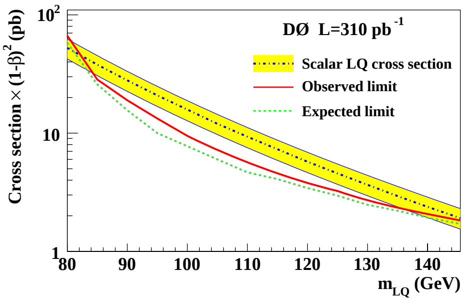

Fig. 4. Observed (solid) and expected (dash) 95% C.L. excluded cross-section $\times(1-\beta)^2$ as a function of M_{LQ}, compared to the theoretical cross section for $\beta = 0$ (dash-dot) also showing the effect of systematic uncertainties (colored band).

Their intersection allows to set a limit $M_{LQ} > 136$ GeV, the most stringent limit to date for 1st and 2nd generation LQ's for $\beta = 0$. This result is now published [10].

3.2. *Third generation Leptoquarks (LQ_3) analysis*

In addition to applying selection criteria very similar to the generic LQ search described above, the 2 jets are required to be b-tagged. After all cuts, for $M_{LQ} = 200$ GeV, 1 event is observed for $3.47 \pm 0.24(stat.)$ expected from SM background and $8.8 \pm 0.2(stat.)$ expected from signal. Since no excess of events is seen and since the contribution from the instrumental background is estimated to be very small, it is conservatively neglected in setting limits for the production of 3rd generation LQ's. Including systematic uncertainties, the observed 95% C.L. excluded cross-section can be compared to theoretical predictions (Fig. 5), where the fact that when $M_{LQ} > m_t + m_\tau$, LQ_3 could decay in $t\tau$ in addition to $b\nu$, is also taken into account. The result is a M_{LQ} limit of 213 GeV when the $t\tau$ decay is open and 219 GeV otherwise.

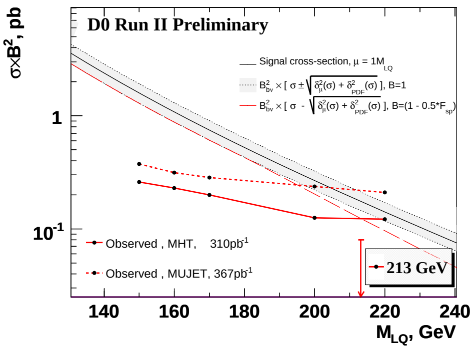

Fig. 5. Observed 95% C.L. limit on $\sigma B^2(LQ_3 \to b\nu)$ (points and solid line) as a function of M_{LQ} compared to the theoretical predictions (solid line) including systematic uncertainties (colored band), with and without taking $LQ_3 \to t\tau$ into account.

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